Blue Green Solutions to mitigate urban heat islands - High resolution modelling of thermo-hydric fluxes

Scientific context:
Urban areas are facing a broad range of challenges due to unsustainable urbanization, degradation of natural capital, as well as an expected increase in intensity and frequency of extreme weather events due to climate change. This should directly exacerbate the environmental impacts (stormwater management) or indirectly (urban heat island and biodiversity degradation) related to the water cycle. Blue Green Solutions (BGS), such as green roofs or vegetated swales, are particularly efficient to reduce the potential impact of new and existing urban developments with respect to these issues. Although BGS benefits are well perceived, some methodologies and tools have to be developed to better understand their thermo-hydric behaviour, and to assess their performances through scales (from the material to the development project).

Such a tool able to assess these environmental performances has not been achieved for now because of the complexity of the urban environment and several scientific issues that must be overcome: (i) poor knowledge about the physical processes involved in the thermo-hydric BGS behaviour (and especially infiltration and evapotranspiration), and (ii) lack of a modelling tool coupling thermic and hydrological functioning at the urban scale.

Objectives:
To address these issues, the proposed Post-Doc position will study the thermo-hydrologic behaviour of BGS. It is particularly focussed on:

- Coupling (physically and numerically) hydrology, thermic & the corresponding eco-system services provided by BGS,
- Characterizing the spatio-temporal variability of the related processes over a wide range of scales (from the material to the district scale);
- Contributing to the development a user-friendly platform to assess thermo-hydric services provided by BGS at the district scale.

Work plan:
The Post-Doc will develop a thermo-hydric coupling. It will be obtained by combining two existing models adapted to urban environment: Multi-Hydro and SOLENE-microclimat. These models have recently been improved to represent a set of possible BGS, and to assess their performances in stormwater management and outdoor comfort respectively. Taking advantage of their modular and distributed structure, the resulting coupled model will be able to simulate BGS performances at different scales (from the building to the district). It will compute and represent the outdoor thermal comfort (temperature distribution) and stormwater management (stored volume of water and resulting runoff) provided by BGS.

The calculation of local climate condition in SOLENE-microclimat (wind velocity, air temperature and humidity, radiative flux) gives a better estimation of

solicitations to which vegetation is submitted. But evapotranspiration rate is currently estimated by using the Penman-Monteith equation. Essentially based on meteorological data, this formulation does not take into account the influence of soil moisture status, neither the type of vegetation. Multi-Hydro will be used to couple thermic and hydrological behavior of BGS and estimate latent heat flux depending on soil water content and vegetation.

An attention will be particularly paid on the numerical aspects: interactions between 2-D fields and 3-D volumes, and different resolution methods (finite volume for SOLENE) and for Multi-Hydro (finite differences).

The coupled model will be applied on the ENPC Campus where a large green roof (called Green Wave, 1 ha) is implemented. The developed thermo-hydric model will be validated by using some experimental data conducted on the Green Wave. A particular attention will be paid to assess the model ability in reproducing latent heat flux, sensible heat flux, water content, infiltration and runoff (according to the available data). Some specific criteria could be defined to take into account the associated spatio-temporal variability and to select the most reliable set of parameters.

Finally, an interface will be developed to assess the implementation of BGS at the scale of an urban project. Based on the coupled model and using climatic scenarios, quantitative indicators will be computed to test the relevancy of these BGS arrangements. Some efforts will be done to transform the model output (infiltration and evapotranspiration rates, discharge, temperature flux...) in defined thermo-hydric quantitative indicators, and to take into account the associated spatio-temporal variability. Some maps or graphs will also be produced if necessary.

Research framework:
This Post-Doc will be carried out into the framework of the EVNATURB ANR French project. EVNATURB aims to develop a platform to assess some of the eco-system services (i.e. stormwater management, cooling effect, or biodiversity conservation) provided by Blue Green Solutions at the district scale, and to promote the re-naturation of cities. Based on a consortium of researchers belonging to Ecole des Ponts ParisTech, Cerema Ouest, Cerema Ile-de-France, and AgroParisTech, EVNATURB intends to put an emphasis on an interdisciplinary, multi-scale and multi-physics approach.

The Post-Doc in charge of this coupling will participate to some training courses to handle both softwares, and will be helped in her/his tasks by local modelling experts.

Profile:
The candidate should have skills in the mathematical modelling of mechanics (PhD in fluid mechanics or environmental physics). Interested in environmental applications, she/he has capabilities in computer simulations (C ++ and Python languages) and 2D and 3D objects manipulation.

Administrative part:
This 12-month Post-Doc will be hosted from the Hydrology, Meteorology and Complexity laboratory at Ecole des Ponts ParisTech (HM&Co/ENPC, Champs-sur-Marne) under the supervision of:

- Pierre-Antoine VERSINI (HM&Co, ENPC), researcher in hydrology and coordinator of the EVNATURB project
- Auline RODLER (CEREMA Nantes), researcher and expert in microclimatology

Some days in Nantes are planned at the beginning of the position to learn about SOLENE-microclimat.

The Post-Doc position should start in August-September 2021.

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References

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Musy, M., Malys, L., Inard, C., 2017. Assessment of Direct and Indirect Impacts of Vegetation on Building Comfort: A Comparative Study of Lawns, Green Walls and Green Roofs. *Procedia Environmental Sciences*, 8, 603-610, DOI : 10.1016/j.proenv.2017.03.134